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Stratigraphic and Palaeoenvironments of Jeribe Formation in Jambur-72 and Ajeel-4 Wells Northern Iraq

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ABSTRACT

This study interests with the Jeribe Formation which deposited during the Langhian (Early Middle Miocene) age with determination the depositional palaeoenvironment in depending on the microfacies analysis in two selected wells from Jambur and Ajeel oilfields northern Iraq. The thickness of the formation reaches about (48 m) in well (Ja.72) and it reaches about (80 m) in well (Aj.4). Independent on the description of cutting samples and interpretation of logs' behavior beside the final well reports, the formation comprises three lithofacies; dolomitized limestone, marly limestone and anhydritic dolomitized limestone. Both its lower and upper contacts are unconformable with the Dhiban and the Fat'ha formations respectively.

A petrographical study was made by using forty five thin sections (18 thin sections from well Aj.4 and 27 from well Ja.72) in order to identify the microfacies and the diagenetic features. The formation consists of four main microfacies with four submicrofacies; Wackestone Microfacies which include Algal-Bioclats Wackestone Submicrofacies (AW) and Fossiliferous Wackestone Submicrofacies (FW), Packstone Microfacies that consists of Bioclats Packstone Submicrofacies (BP) and Miliolidal Packstone Submicrofacies (MP), Bioclats Grainstone Microfacies (BG) and Dolomitized Mudstone Microfacies (DM). The dolomitization, cementation, recrystallization, dissolution and compaction are the most partaken diagenetic features with these microfacies which affected on the porosities of the formation by either reducing or increasing them where cementation, recrystallization early stages of compaction and late stages of dolomitization reduced the porosity while the dissolution, early stages of dolomitization and late stages of compaction increased the porosity. The formation has a medium porosity represented by interparticles, intraparticles and intercrystalline as primary porosity, whereas secondary porosity include moldic, fracture, channel and vug porosity

In accordance to the microfacies associations, the formation was deposited in shallow lagoon with quiet warm water conditions with open to restricted circulation in various palaeoenvironments represented by subtidal, tidal and supratidal flats within inner to middle ramp setting.

Keywords: Jeribe Formation, Jambur, Ajeel, Microfacies, Palaeoenvironment and oilfield

Introduction

The Jeribe Formation is studied in two wells from Jambur (Ja.72 and Aj.4) and Ajeel oilfields respectively. Jambur oilfield sites southeast Kirkuk city as a longitudinal structure with 36 km length and (4-6 km) width, whereas Ajeel oilfield is located about 30 km northeast Tikrit city in Salahaddin

governorate and it consists of two domes which are separated by a narrow saddle (southwest dome which is considered the main dome and northwest dome) and it extends parallel to the Nukhaila dome in Hamrin oilfield with 40 km length and 5 km width (Table 1).

Table 1: Coordinate of the studied wells with the depths of the top, bottom and the thickness of Jeribe Formation

Well	UTM Coordinates		Top of Formation (m) RTKB	Bottom of Formation (m) RTKB	Thickness (m)
	E	N			
Ja.72	444133	3903603	2067	2115	48
Aj.4	394407.3	3861592.4	860	940	80

Tectonically, Jambur oilfield is located in the Butmah - Chemchamal Subzone, while Ajeel structure is situated in the Hamrin - Makhul Subzone within the Foothill Zone a part of the Unstable Shelf of Arabian

Plate which characterized by longitudinal anticlines with northwest - southeast directions with Zagros framework as a result of Alpine Orogeny during the

end of the Tertiary Period [Jassim and Goff, 2006] (Fig. 1).



Fig. 1: Location map of the study area

Buday, [1980] mentioned that the Jeribe Formation is belong to the Middle Miocene Subcycle which associated with a transgression reached the Balambo - Tanjero Zone in the northeast of Iraq. During this transgression carbonate sediments bearing oyster of Govanda Formation were deposited, and the whole Foot hill Zone was covered by this transgression which marked by carbonate and evaporated carbonate sediments [Jassim and Goff, 2006]. The studied area was covered by shallow carbonate lagoonal sediments of Jeribe Formation (Fig.2).

The formation was first described by [Damensin, 1936 in Bellen *et al.*, 1959]. Then, Bellen *et al.*, [1959] prescribed the type section of the formation in Jaddala village near the Sinjar Mountain as massive

recrystallized dolomitic limestone. The age of the formation is suggested as Early Middle Miocene depending on the biostratigraphy study by [Ctyrocky and Karim, 1970]. The microfacies study of the Tertiary Period in Iraq by [Al-Hashimi and Amer, 1985] referred that the formation was deposited in a saline warm quiet shallow marine conditions. In accordance to the diagnosed species *Borelis melo curdica* of benthonic foraminifera and the species *Orbulina* of planktonic foraminifera with red algae and basal conglomerate, the age of Jeribe Formation was determined as Early Middle Miocene [Al-Jwaini, 2000]. The formation has been deposited in a lagoon environment within ramp setting [Aljwaini and Gayara, 2016; Hussein *et al.* 2017].

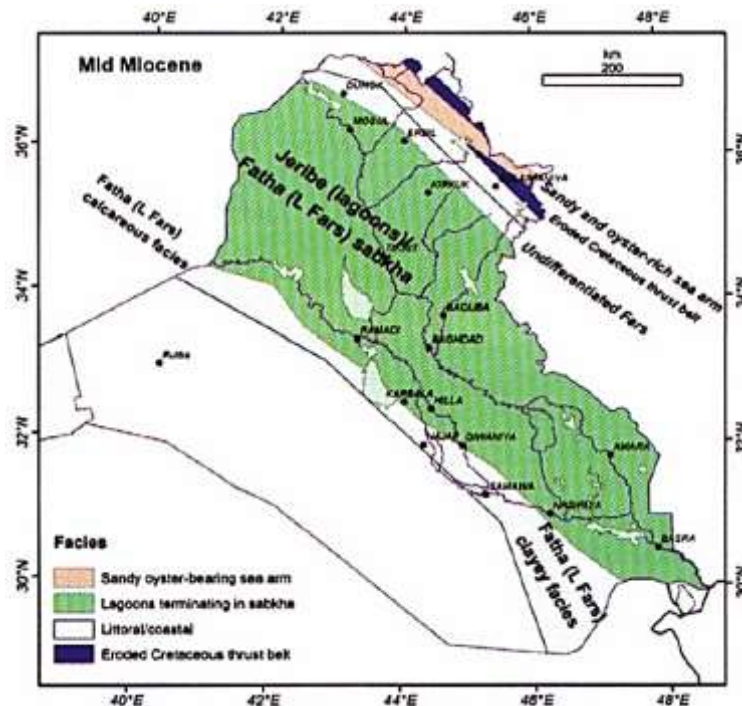


Fig. 2: Geological formations of Middle Miocene Subcycle from (Jassim and Goff, 2006)

This study aims to evaluate the depositional setting and determining the palaeoenvironments depending

on petrographic study, lithological description and microfacies analysis and give a wider knowledge of

the stratigraphy of the Jeribe Formation which is considered an important hydrocarbon reservoir in Jambur and Ajeel oilfields.

What is the new conclusions from this study and how different from previous studies specially from the point of microfacies and paleo environment.

Methodology

The final well reports of the selected wells and the previous studies with available data about the Jeribe Formation in North Oil Company have been reviewing in details and a lithological description was applied on selected samples carefully in order to subdivide the formation into different lithofacies.

Forty five thin sections (18 from well Aj.4 and 27 from well Ja.72) including thirty five slides are borrowed from the Geology Department in the North Oil Company in addition to ten cutting samples which are thin sectioned in the Applied Geology Department in Tikrit University were used in this study. These thin sections were treated with Alizarine Red Solution to distinguish between the limestone and dolomite carbonates. Then, they were carefully studied under the polarized microscope using the classification of carbonate rocks suggested by [Dunham, 1962] and improved by [Embry and Klovan, 1971] to describe the microfacies association and the combined diagenetic features with employing interpretations of different well logs information in order to determine the palaeoenvironments of Jeribe Formation in the two selected wells from Jambur and Ajeel oilfields.

Stratigraphy and lithology

The Jeribe Formation is considered as one of important hydrocarbon reservoir in northern Iraq [Jassim and Goff, 2006], it exposes in northwest and west parts while it has subsurface occurrence with high thickness in the Jambur, Pulkhana and Injana area. In contrast, the formation is not found in southern Iraq [Bellen *et al.*, 1959]. The formation has thickness reached to (48 m) in (Ja.72) and it increased to (80 m) toward the southwest in (Aj.4) of Ajeel oilfield. Both, the lower contact with Dhiban Formation and the upper contact with Fat'ha Formation are unconformable as they are concluded from changing in lithological facies and fauna content rather than well logs indicating.

The formation is comprised from three lithofacies which characterize a shallow marine facies from top to bottom as following (Figs. 3 and 4):

1. Unit (A)

This unit is recognized in the lower part of the formation in both studied wells underlying the marly limestone facies. It composed of dark brown dolomitized limestone facies graduate to narrow brittle bands of marly limestone toward the bottom of the formation. It has high thickness especially in well (Aj.4) where it exceeds about (20 m) occupies the depths (940-920m), while it reaches about (15 m) in well (Ja.72) and it located at depths (2115-2100m). It consists from different fragments of algae,

Pelecypoda and Echinoderms plates in well (Ja.72) while the benthonic foraminifera represent the skeletal grains of this unit in well (Aj.4).

2. Unit (B)

This unit consists of greenish-greyish marly limestone interbedded with streaks of marl and it is distinguished in the middle part of the formation underlying the dolomitized limestone facies of unit (C) where it located at depths (920-870 m) with (50 m)thick in (Aj.4) and (20 m) thick in (Ja.72) where it occupies depths (2100-2080 m). The skeletal grains in this unit are consisted of many shell debris.

3. Unit (C)

This unit overlying the marly limestone facies of unit (B) in both wells, where it represented by grey dolomitized limestone in the middle and upper parts of the formation, sometimes contain anhydrite nodules in well Aj.4. It has thickness about (10 m) in well (Aj.4) and occupies the depths (870-860 m), while it is located at depths (2080-2067 m) with thickness about (13 m) in well (Ja.72). Most skeletal grains of this unit suffered from dolomitization and anhydritization diagenesis which destroyed the appearance of the grains and left them as ghosts only.

Petrography

The petrographic study is a fundamental in the microfacies analysis and description to conclude the depositional palaeoenvironments and the sea level changes where the different textures of carbonate rocks reflect the imparity of depositional conditions of specific environment [Milliman, 1974]. The components of carbonate rocks consist of particles and matrix [Flugel, 1982].

Many types of skeletal particle have been recognized in this study such as different genus of benthonic foraminifera, Miliolids, Rotalids rather than bioclasts, Ostracods, Echinoides, Gastropods and Algae. On the other hand, the non-skeletal particles are represented by rarity of lithoclasts and pellets. The matrix is mainly characterized by micrite and rare sparite which produced due to the recrystallization diagenesis process affecting on micrite.

Microfacies Associations

The main objective of microfacies analysis is to provide more details about the characterization of carbonate rocks (such as the type, size and shape of grains beside the nature of matrix, cement and texture) which related with environmental conditions. Therefore, it has a substantial importance in determination and interpretation of palaeoenvironments.

In this study, the microfacies are distinguished according to Dnham's, [1962] classification of carbonate rocks which developed by Embry and Klovan, [1971] and compared with the standard microfacies (SMF) and facies belt zones (FZ) of [Wilson, 1975] improved by [Schlager, 2005] of carbonate ramp environments . Four main microfacies with four submicrofacies are recognized in Jeribe Formation as below:

1. Wackestone Microfacies

This microfacies contains low amount of marl and it is existed in the lower and middle parts of the formation. It includes two submicrofacies:

A. Algal-Bioclasts Wackestone Submicrofacies (AW)

This submicrofacies is found within the lower parts of the formation in well (Ja.72) of Jambur oilfield, and it is located at the depths between (2115-2100 m) with (15 m) thick. It comprises mainly from red algae in addition to bioclasts of Pelecypoda, Echinoides and Gastropoda within micrite matrix. The dissolution and dolomitization are the most diagenetic features associated with this submicrofacies which has medium channel and intraparticles porosity (Pl.1A). In accordance to [Wilson, 1975; Schlager, 2005], this microfacies is similar to the standard microfacies (SMF18) which deposited within the facies belt zone (FZ7) and indicate to a shallow marine relative lagoon with open circulation.

B. Fossiliferous Wackestone Submicrofacies (FW)

This microfacies is recognized in the lower part of the formation in both wells (Aj.4) occupies the depths (940-922 m) with thickness reach to (18 m), and (Ja.72) at the depths (2100-2088 m) where it has thickness about (12m). *Miliolids*, *Denderitina rangi*, *Peneroplis* sp., Rotalid and echinoderm plates are main skeletal grains in this microfacies which suffered from cementation, stylolitization and recrystallization diagenesis process that causes low intraparticles porosity only (Pl.1B and C).

The occurrence of Echinoderm plates refer to a normal open marine with moderate to low energy conditions.

This submicrofacies resemble with the standard microfacies (SMF8) which deposited within facies belt zone (FZ7) that indicate to shallow subtidal lagoon within inner ramp.

2. Packstone Microfacies

This microfacies is existed in the lower and middle parts of the formation alternating with the wackestone microfacies and it comprises two submicrofacies:

A. Miliolidal Packstone Submicrofacies (MP)

This submicrofacies represents the lower and middle parts of the Jeribe Formation in both wells where it located at the depths (900-922 m) in well (Aj.4) with (22 m) thick, while it occupied the depths (2075-2088 m) with thickness (13 m) in the well (Ja.72). This microfacies is characterized by abundant Miliolids but with low diversity, bivalves, Gastropods and Echinoderm plates in micrite matrix. It has been suffered from dolomitization, cementation and recrystallization diagenesis (Pl.1D).

The biological and lithological components of this submicrofacies are compatible with the (SMF18) in (FZ.8) which refer to the deposition were took place

in a shallow lagoon environment with restricted water circulation within inner ramp setting [Geel, 2000; Flugel, 2010].

B Bioclasts Packstone Submicrofacies (BP)

This microfacies represent the middle part of the formation in well (Aj.4) with (18 m) thick and it occupies depths (900-882 m), whereas it is diagnosed in the upper part of the formation in the well (Ja.72) with thickness of (8 m) where it is located at depths (2075-2067 m). Abundant Pelecypoda shells debris, Gastropods, Echinoids debris and spines with Rotalids characterize the main skeletal grains of this microfacies in addition to rare coexisting of Ostracoda and lithoclasts within micrite matrix (Pl.1 E). The dissolution, compaction, mechanical degradation, cementation, stylolitization and anhydritization are the most diagenetic features combined with this microfacies which has medium moldic, interparticles and intraparticles porosities.

The abundance presence of Pelecypoda shells refer to a shallow lagoon environment within inner ramp with normal salinity [Lomando and Gischler, 199; Geel, 2000, Flugel, 2010]. This microfacies is similar to the standard microfacies (SMF10) that deposited in facies belt zone (FZ7) which indicates to intertidal flats within inner carbonate ramp.

3. Grainstone Microfacies (G)

This microfacies appears at the upper parts of the formation in the (Aj.4) well where it is located at depths (882-868 m) with thickness (14 m). It composed a high percentage of shell fragments of Gastropods, Pelecypoda and Rotalid within sparite matrix. The most diagenetic features associated with this microfacies are dolomitization, cementation and dissolution (Pl.1 F). This microfacies is similar to the (SMF11) in (FZ6) which refer to shoal environment above fair-weather wave base within the euophotic zone strongly influenced by tidal currents as a narrow facies belt. The existing of Gastropods with high percentage in this facies indicate to a shallow water with high energy above the fair weather wave base within inner ramp settings [Geel, 2000].

4. Dolomitized Mudstone Microfacies (DM)

This microfacies is identified on the top of the formation in well (Aj.4) with thickness reaches (8 m) and it occupies the depths (868-860 m). It consists of micrite with dispersed silt-sized quartz particles with subhedral crystals of dolomite and no funnal content except low occurrence of fossils' ghosts due to the dolomitization, anhydritization and dissolution diagenesis that caused intracrystalline and vuggy porosities except the anhydritization which filled the pores as nodules. (Pl.1 G and Pl.1 H).

This microfacies is conformable with the standard microfacies (SMF23) in facies belt zone (FZ9) which refer to supratidal flat within inner carbonate ramp.

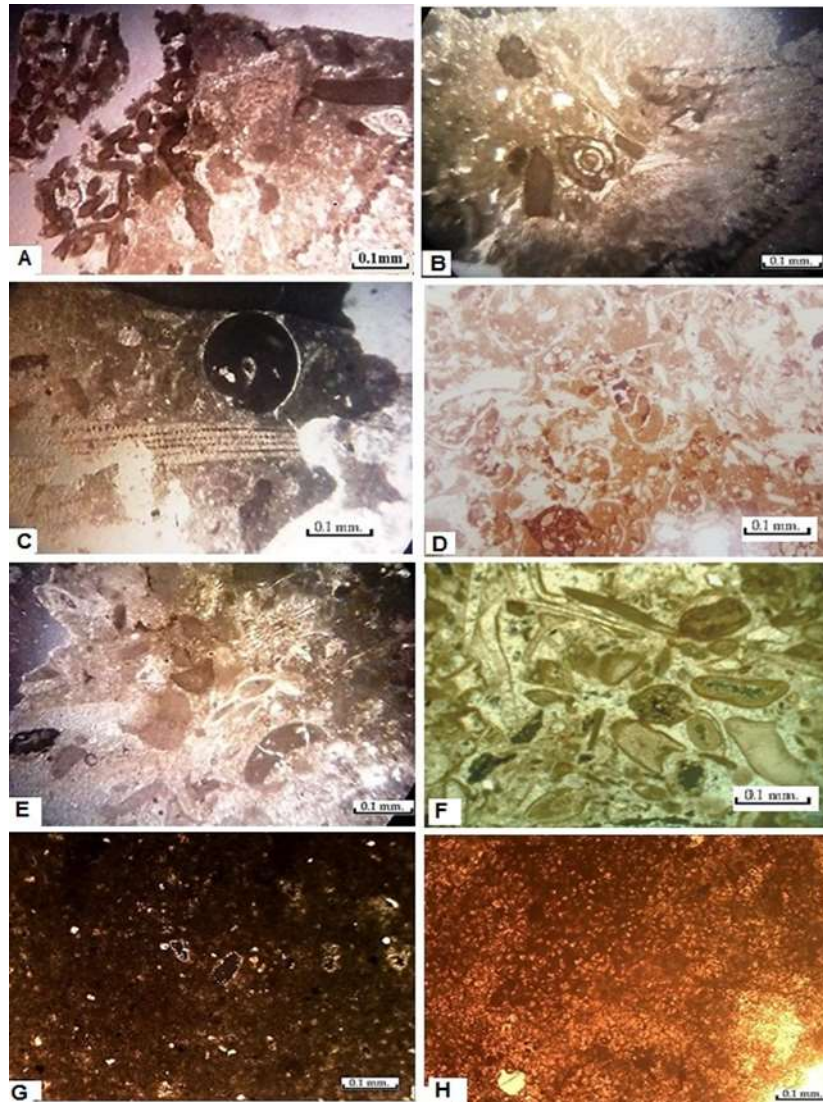


Plate 1: Microfacies of Jeribe Formation in wells (Ja.72) and (Aj.4)

- A. Red algae and bioclasts in micrite matrix with dolomitization within Algal-Bioclasts Wackestone Submicrofacies. Well (Ja.72), Depth (2112 m)
- B. *Miliolid*, shell debris and red algae with cementation and stylolitization in Fossiliferous Wackestone Submicrofacies. Well (Aj.4), Depth (936 m)
- C. Echiniods and *Gastropoda* with micrite matrix in Fossiliferous Wackestone Submicrofacies. Well (Ja.72), Depth (2096 m)
- D. Miliolid, Gastropod, Bivalve and Echinoderm fragments with cementation, dissolution and compaction diagenesis in Miliolidal Packstone Submicrofacie. Well (Aj.4), Depth (902 m)
- E. Variable shell debris in micrite matrix with cementation, compaction, stylolitization and anhydritization diagenesis within Bioclast Packstone Microfacies. Well. (Ja.72), Depth (2070 m)
- F. Shell fragments of Gastropods, Ostracods and benthonic foraminifera (especially miliolids and rotalids) located in sparry calcite cement in Grainstone Microfacies. Well (Aj.4), Depth (878 m)
- G. Dolomitized Mudstone Microfacies with dolomitization and quartz particles and vug porosity. Well (Aj.4), Depth (866 m)
- H. Dolomitized Mudstone Microfacies with dolomitization and cementation. Well (Aj.4), Depth (862 m)

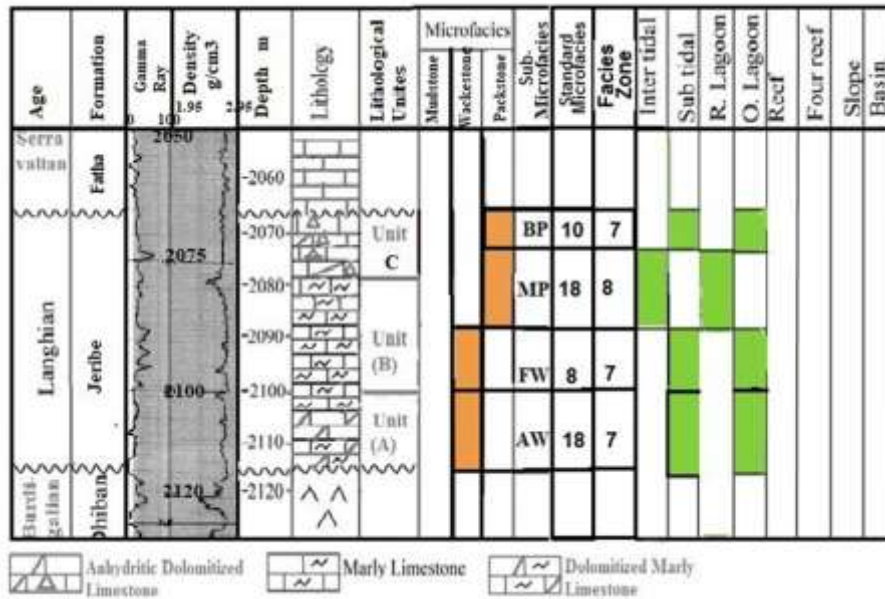


Fig. 3: Palaeoenvironments, Microfacies and lithological Units of the Jeribi Formation in well Aj.4

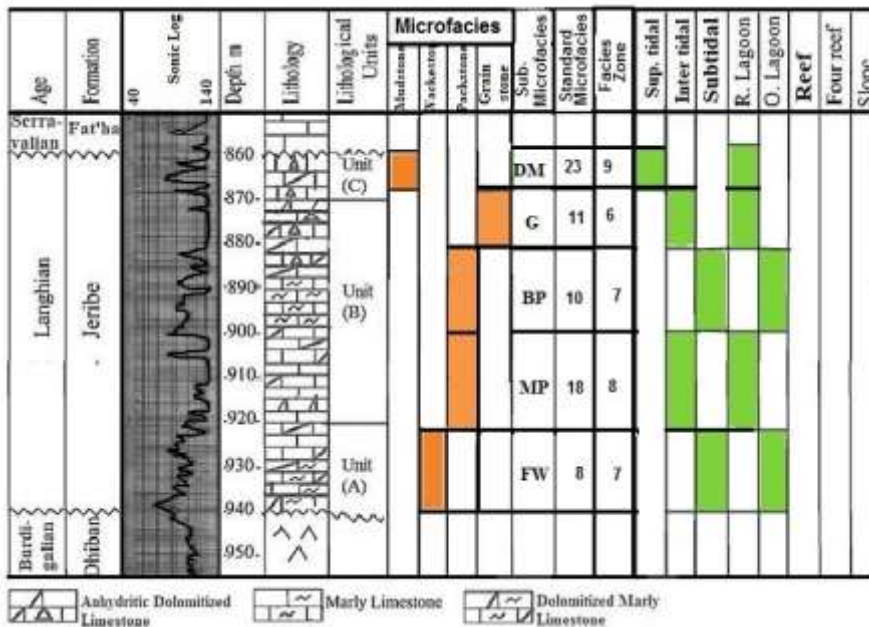


Fig. 4: Palaeoenvironments, Microfacies and lithological Units of the Jeribi Formation in well Ja.72

Palaeoenvironments

The presence of the red algae, pelecypoda and echinoids in the Algal-bioclasts Wackestone Submicrofacies, as well as, the existence of the Rotalid, echinoderm plates with *Peneroplis* in the Fossiliferous Wackestone Submicrofacies give an evidence to a shallow marine relative lagoon subtidal flat with open circulation in ramp setting [Wilson, 1975; Schlager, 2005].

The abundance of Miliolids in the Miliolidal Packstone Submicrofacies (MP) microfacies indicates to a shallow lagoon with restricted water circulation with elevated salinity [Flügel, 2010].

Pelecypoda shells in the Bioclastic Packstone Submicrofacies (BP) refer to intertidal flats with normal salinity of a shallow lagoon environment

within inner ramp [Lomando and Gischler, 199; Geel, 2000; Flügel, 2010].

The shell fragments of the Gastropod, Pelecypods and Echinoderms in the Grainstone Microfacies are indicative a very shallow marine environment with high energy. Also, the absence of the biological components in the Dolomitized Mudstone Microfacies with fine grained quartz in the top of the formation denote a shallow marine with supratidal flat.

Depending on the types, nature and distribution of the identified microfacies during the Early Middle Miocene, this study could imply that the Jeribe Formation represents a regressive depositional cycle with shallowing upward and the deposition has been

took place in a shallow lagoon with restricted to open circulation water passes from subtidal, intertidal flat and supratidal area within patched reef distally steepened ramp setting as it indicated by the low diversity of the miliolids instead of the occurrence of *Peneroplis* so four depositional regimes are responsible on microfacies distribution (Fig.5) as following.

1. Relative open lagoon within inner ramp: This environment is responsible on distribution of Algal Wackestone Submicrofacies.
2. Subtidal flat within inner ramp: This environment contributed in spreading of Fossiliferous Wackestone Submicrofacies.
3. Intertidal flat within inner ramp: This microfacies is interrupted on disseminating of Miliolidal Packstone Microfacies, Bioclasts Packstone Microfacies and Grainstone Microfacies.
4. Supratidal flat within inner carbonate ramp: this environment controlled on deposition of Dolomitized Mudstone microfacies.

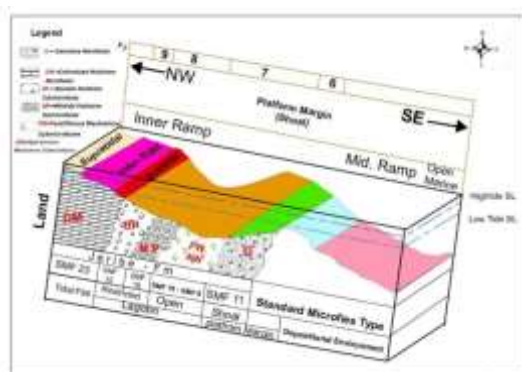


Fig. 5: Depositional Model of Jeribe Formation

Conclusions

Upon the lithofacies and microfacies analysis of Jeribi Formation in two selected wells from Ajeel and Jambur oilfields, many conclusions have been reached in this study as below:

1. The Jeribe Formation is comprised from three lithofacies; dolomitized limestone with bands of dolomitized marly limestone in the lower part of the formation, marly limestone in the middle part and

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anhydritic dolomitized limestone in the upper part of the formation.

2. The formation is consisted of four microfacies with four submicrofacies; wackestone microfacies which include the Algal-Bioclasts Wackestone Submicrofacies represent the lower part of the formation in well Ja.72 and Fossiliferous Wackestone Submicrofacies characterize the lower part of the formation in both studied wells, Miliolidal Packstone Submicrofacies in the lower and middle parts in both wells, Bioclast Packstone Microfacies in the middle and upper parts of the formation in both studied wells, Grainstone and Dolomitized Mudstone Microfacies in the upper part of the formation in the well (Aj.4).

3. The formation suffered from many diagenesis process that affected on the porosity such as cementation, anhydritization recrystallization and compaction that reduce the porosity, conversely the primary stages of dolomitization dissolution and the mechanical degradation diagenesis led to enhance the porosity while the progressive late stage of dolomitization reduced the porosity.

4. The microfacies associations of the formation reflect a regressive cycle shallowing upward.

5. Both lower and upper contacts of the formation with the Dhiban and Fat'ha formations respectively are unconformable due to the changing in fauna contents and lithology rather than the well log records.

6. The types of porosity existed in the formation are intraparticles, interparticles and intercrystalline porosities as primary porosity instead of that the moldic, channel and vuggy porosities as secondary porosity.

7. The types, nature and distribution of the microfacies indicate that the deposition of the formation was took place in four palaeoenvironments within inner ramp represent the depositional setting of the formation as indicated from the low diversity of miliolid instead of the occurrence of the *Peneroplis*. These palaeoenvironments are represented by shallow lagoon with open to restricted water circulation, Subtidal flat, Intertidal flat and Supratidal flat within ramp setting.

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